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THE NEW NAVIGATION

BY L. B. STEWART

THE method used for determining the position of a ship at sea, popularly known as the New Navigation, is not really very new, as it was proposed about forty years ago by Marcq St. Hilaire, a French admiral. It was soon introduced into the navy, where its advantages were at once recognized, but it is only now coming into use in the merchant service. Like Sumner's method, of which it is strictly speaking a modification, it makes use of "lines of position", or Sumner lines, to determine by their intersection the position of a point of observation; and only differs from that method in the means by which those lines of position are found.

It is proposed here to give a brief account of the methods that have been used for finding a ship's position by taking two observations of a heavenly body, allowing a considerable interval of time to elapse between them, or of two heavenly bodies at as nearly as possible the same time; and then plotting the resulting lines of

position on a chart. The result of some observations at Toronto will also be given, which were taken in order to test the precision of the graphical process, and the applicability of the method to the use of the explorer on land.

Sumner appears to have stumbled upon the method that bears his name purely by accident. Sailing from Charleston, S.C., in 1837, bound for Greenock, Scotland, he found himself after a stormy voyage approaching the coast of Ireland in a southerly gale, having had no opportunity for some days for taking an observation to determine his position, and with his dead-reckoning very unreliable. About 10 o'clock in the forenoon of a certain day the sun came out, and he at once took an observation, noting the Greenwich time. The best he could do was to use his dead-reckoning latitude in reducing this observation, which he did, finding the corresponding longitude. Not being satisfied with this result he then assumed two other latitudes in turn, one 10′, and the other 20′, north of his dead-reckoning position, and deduced the corresponding longitudes. He then plotted the three positions thus found on his chart, and found that they all lay on the same straight line, which bore E.N.E. This line when produced passed through the Small's Light; and he put his ship on that course, and in about an hour sighted the light almost dead ahead. He concluded that the same observation might have been taken at any one of the three assumed positions, at the actual position of the ship, and at the Small's Light.

The line which Captain Sumner thus drew on his chart was a small portion of the circle of position,—so small, relatively to the whole, that its curvature was not apparent—whose centre or pole was the point on the earth's surface vertically under the sun, and whose angular radius was the sun's zenith distance as given by the observation. The point vertically under the sun, or the sub-solar point, of such a circle evidently lies on the meridian whose longitude is equal to the sun's hour angle at Greenwich, and its latitude is equal to the sun's declination. At any point on such a circle the same observation may be taken.

In Fig. 1 is shown a stereographic projection of the circles of position determined by the observations of the sun taken at Toronto on February 18th, 1919, the results of which are given below.

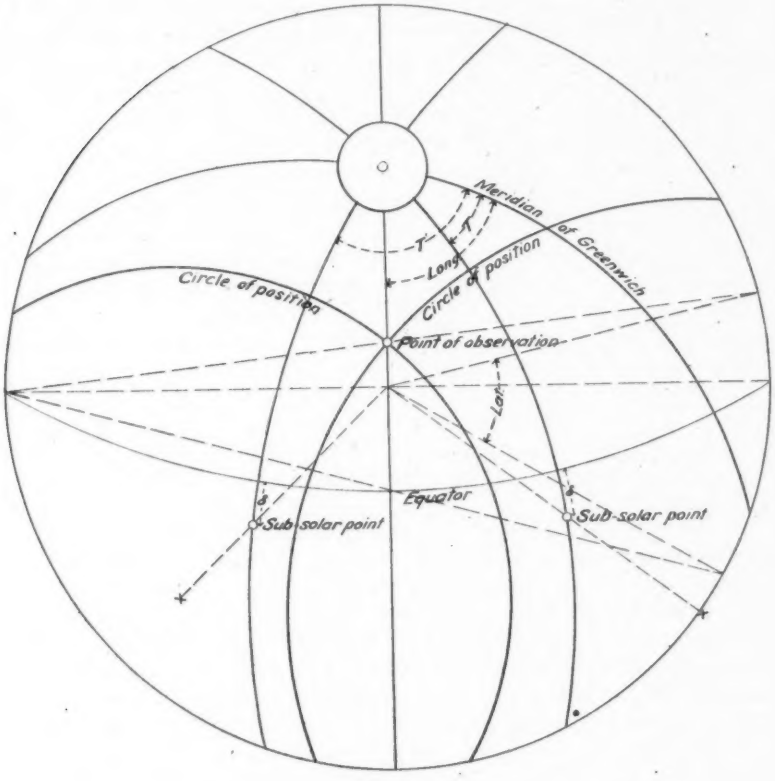


FIGURE 1

Stereographic projection circles of position, observations of the sun, Feb. 18, 1919

Sumner's next step was to take a second observation of the sun about two hours after the first, and to reduce it in the same manner, using in turn two assumed latitudes, and computing the two corres-

ponding longitudes. Thus two points were found on a second line of position, which was also plotted on the chart.

The intersection of the two lines of position would give the position of the ship if it had been at anchor between the two observations. In the interval, however, it had sailed 50 miles on a course E. by N., and the method of allowing for the run of the ship is best shewn by the aid of Fig. 2 (not drawn to any scale).

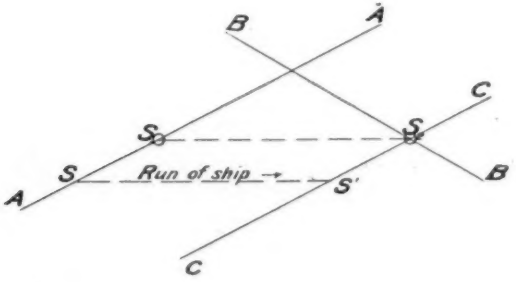


FIGURE 2.

In that figure AA is the first line of position, and BB the second; and it is necessary to find two points, one on each of these lines, at a distance of 50 miles apart on a course E. by N. This is best done by drawing a line on the given course through S, the dead-reckoning position at the first observation—or through any point near the intersection of the two lines of position. Then, to find the length of this line on the chart, compute, or take from a table, its departure, and multiply that quantity by the secant of the latitude, thus finding the difference of longitude covered between the observations. The meridian given by that difference of longitude will intersect SS′ in the required point S′. If the course of the ship between the observations were to lie more nearly north and south than east and west, then the length SS′ is best cut off by means of a parallel of latitude found by reducing the run of the ship to meridional difference of latitude.

Having plotted on the chart the course sailed over between the observations a line is then drawn through S′ parallel to AA; its intersection S_2 with BB is the position of the ship at the second observation. A line through S_2 parallel to S′S determines S_1, the position at the first observation, if this is required.

This was the original Sumner method of determining the ship's position on a chart, and it entailed a considerable amount of labor, as it was necessary to compute four longitudes from the observations. As soon, however, as the fact was realized that these position lines are portions of circular arcs whose centres lie vertically under the sun—or other body observed—it was perceived that the direction of such a line is perpendicular to that of the sun. It was then only necessary to determine the azimuth of the sun in order to find the direction of a line of position, and this may be done either by the aid of tables or diagrams, or by means of a compass bearing. One point on such a line would then determine it completely, and that point was given by the observation, from which the longitude was computed, using in the reduction the latitude found by dead-reckoning.

This method is illustrated in Fig. 3, in which S and S″ are the first and second dead-reckoning positions, AA and BB the two lines of position, SS′ the run of the ship between the observations, CC a line through S′ parallel to AA and intersecting BB in the point S_2, the position of the ship at the second observation. S_2 S, drawn parallel to S′S gives S_1, the position of the ship at the first observation.

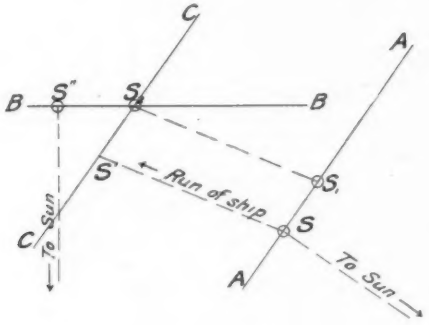


FIGURE 3

If one of the observations is a meridian altitude of the sun the work is considerably shortened, as in that case the resulting line of position is a parallel of latitude, and no longitude computation is necessary.

The next improvement, proposed by St. Hilaire, may be described as follows. If an altitude of a heavenly body be observed, and the Greenwich time noted, the latter, combined with the right ascension of the body and the dead-reckoning longitude of the place of observation, will give the approximate hour angle of the body. If its altitude be now computed, using as data the hour angle as just found, the declination, and the dead-reckoning latitude, that altitude will generally differ from the value found by observation, as the position of the point of observation, as given by dead-reckoning, will not usually be exactly on the circle of position. The amount of the difference shews how far the assumed point is outside or inside the circle of position, measured radially. The computed altitude minus the observed evidently gives the distance the dead-reckoning position is *inside* the circle of position. The azimuth of the heavenly body must also be found, as in the last method.

In applying this method the procedure then is to compute the altitude of the heavenly body, as above described, and also its azimuth; then to subtract the observed from the computed altitude. Through the dead-reckoning position of the point of observation a line is then drawn in the direction of the heavenly body observed, and on this line is laid off the above difference in minutes between the two altitudes, away from the body if positive, towards it if negative. Through the point thus found the line of position is drawn perpendicular to the direction of the body observed.

The application of this method is illustrated in Fig. 4, in which S is the first dead-reckoning position; SD the difference between the computed and observed altitudes; AA the first position line; DS′ the run of the ship between the observations; S′E the difference between the two altitudes by the second observation; BB the second position line; CC a line through S′ parallel to AA, giving S_2 the position of the ship at the second observation; S_1 is its position at the first.

In using this method a favorite course with some navigating officers is to observe, in the early morning, the altitude of a planet,

which is bright enough to be easily seen after the sea horizon becomes visible. An hour or two later the sun is observed, thus completing the data for finding the two position lines without allowing too long an interval of time to elapse between the observations, and so minimizing the error due to faulty dead-reckoning. The best results are obtained when the azimuth of the body or bodies observed differ by 90° at the instants of observation.

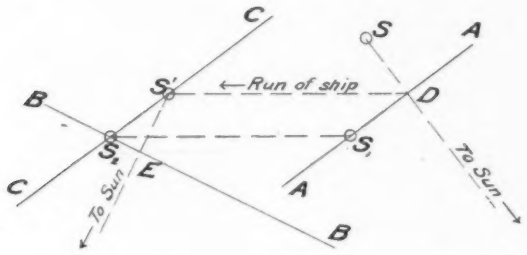


FIGURE 4

In order to facilitate the application of the St. Hilaire method plotting sheets are published on which the meridians and parallels are drawn in Mercator's projection, on a fairly large scale, for different latitudes up to 60°. In the absence of these sheets, ordinary cross-section paper, divided to twentieths of an inch or in millimeters, answers almost equally well; and it has the advantage of allowing the computer to choose his own scale. Moreover its scales of equal parts serve not only for setting off latitudes and longitudes, but also azimuths and perpendiculars, so that both scale and protractor may be dispensed with in constructing a diagram. A table of meridional parts is of course necessary.

Tables also have lately been published which give the altitude of a heavenly body in terms of the latitude, declination, and hour angle; and as azimuth diagrams and tables have been in use for some time, the labor of the navigating officer in determining his position at sea is thus reduced to a minimum, so that he is in danger of forgetting the use of logarithms.

In order to test the precision of the graphical process, and the usefulness of the method to the explorer on land, some observations were taken at Toronto by the writer with a 10-inch theodolite reading to single seconds, and others with a 4-inch theodolite

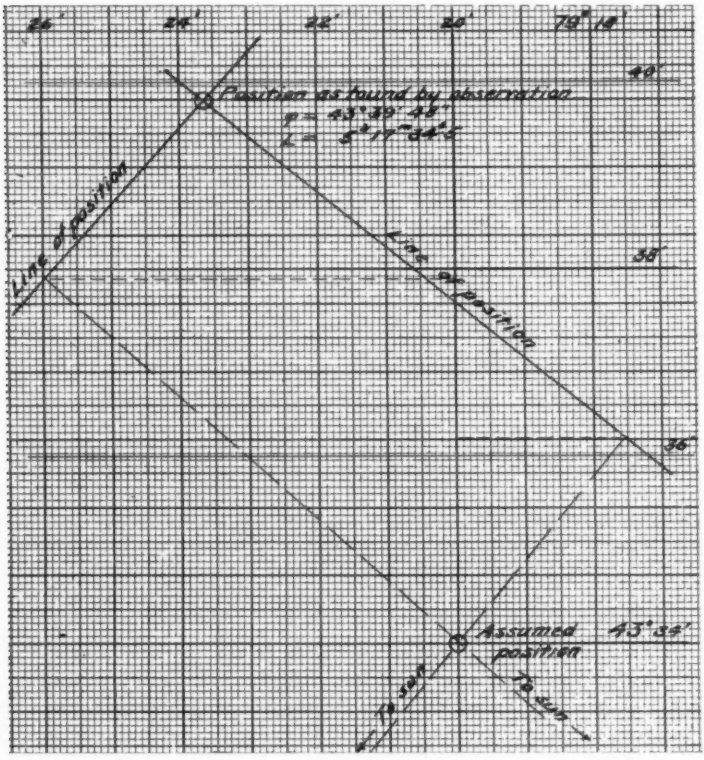


FIGURE 5

reading only to single minutes. The resulting graphical constructions, shewn in Figs. 5 and 6, were made on cross-section paper divided to 1/20 of an inch, one inch representing two minutes.

The meridional parts were computed specially, allowing for the spheroidal form of the earth.

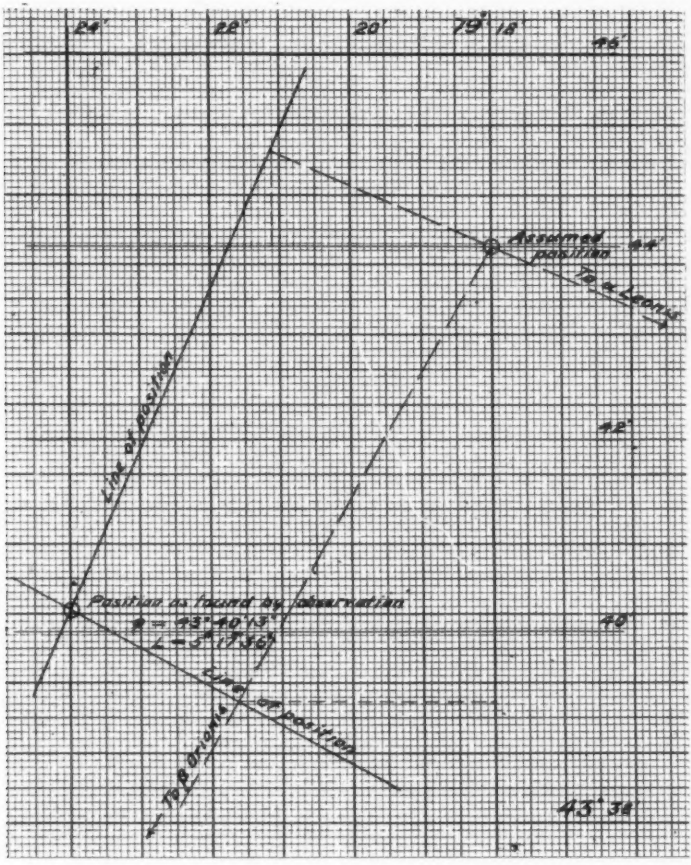


FIGURE 6

The following observations of the sun were taken with the larger instrument on March 18th, 1919:

	Obs. alt.	*G.M.T.*
1st obs'n.	21° 05′ 17.″7	$2^h 31^m 54.^s 96$
2nd obs'n.	25 57 34. 9	7 52 44. 15

The assumed position of the point of observation was:

$$\phi = 43° 34', \quad L = 5^h 17^m 20^s .$$

The formulæ used in the reduction were:

$$\tan \theta = \frac{\tan \delta}{\cos \tau}$$

$$\sin h = \frac{\sin \delta \cos (\theta - \phi)}{\sin \theta}$$

$$\tan A = \frac{\tan \tau \cos \theta}{\sin (\theta - \phi)}$$

in which: ϕ denotes the latitude,
δ the declination,
τ the hour angle,
h the altitude,
A the azimuth, and
θ an auxiliary angle.

The reduction is as follows:

Obs'd. alt.	= 21° 05′ 17″.7	= 25° 57′ 34″.9
r	= 2 36 .6	= 2 04 .8
	21 02 41 .1	25 55 30 .1
p	= 8 .3	= 8 .0
h (observed)	= 21 02 49 .4	= 25 55 38 .1
	h. m. s.	*h. m. s.*
G.M.T.	= 2 31 54 .96	= 7 52 44 .15
E.	= 14 07 .93	= 14 06 .85
G.A.T.	= 2 17 47 .03	= 7 38 37 .30
L (assumed)	= 5 17 20	= 5 17 20

τ	$= 2\ 59\ 32\ .97$	$= 2\ 21\ 17.30$
	$=44°\ 53'\ 14''.55$	$=35°\ 19'\ 19''.5$
δ	$=11°\ 51'\ 45''.4s.$	$=11°\ 47'\ 03''.6s.$

	log	*log*
$\tan\ \delta$	$9.3223260n$	$9.3193674n$
$\cos\ \tau$	9.8503370	9.9116448
$\tan\ \theta$	$9.4719890n$	$9.4077226n$

$\theta=180°-16°\ 30'\ 49''.70$	$=180°-14°\ 20'\ 34''.61$
$=163°\ 29'\ 10''.30$	$=165°\ 39'\ 25''.39$
$\phi=\ 43\ \ 34\ \ 00$	$=\ 43\ \ 34\ \ 00$
$\theta-\phi=119\ \ 55\ \ 10\ .30$	$=122\ \ 05\ \ 25\ .39$

$\sin\ \delta$	$9.3129505n$	$9.3101161n$
$\cos\ (\theta-\phi)$	$9.6979118n$	$9.7253042n$
$\sin\ \theta$	9.4536950	9.3939703
	9.0108623	9.0354203
$\sin\ h$	9.5571673	9.6414500
$h=21°\ 08'\ 39''.36$		$=25°\ 58'\ 29''.26$
$\tan\ \tau$	9.9982927	9.8504124
$\cos\ \theta$	$9.9817060n$	$9.9862477n$
$\sin\ (\theta-\phi)$	9.9378822	9.9279916
	$9.9799987n$	$9.8366601n$
$\tan\ A$	$9.0421165n$	$9.9086685n$

$A=180°-47°\ 46'\ 25''.82$	$=180°-39°\ 01'\ 09''.53$
$=132°\ 13'\ 34''.18$	$=140°\ 58'\ 50''.47$

h (computed)	$=21°\ 08'\ 39''.4$	$=25°\ 58'\ 29''.3$
h (observed)	$=21\ 02\ 49\ .4$	$=25\ 55\ 38\ .1$
Diff.	$=\ 5\ 50\ .0$	$=\ 2\ 51\ .2$

The construction of Fig. 5 explains itself. The resulting position is:

$\phi = 43°\ 39'\ 48''$ $\quad L = 5^h\ 17^m\ 34^s.5$

The observations were also reduced numerically throughout, giving the following values:

$\phi = 43°\ 39'\ 47''.47,$ $\quad L = 5^h\ 17^m\ 34^s.49,$

A comparison of these figures with the last shows the precision of the graphical construction.

The latitude found by several observations with a zenith telescope, and the known longitude, determined telegraphically, are as follows:

$\phi = 43°\ 39'\ 47''.31,$ $\quad L = 5^h\ 17^m\ 34^s.70.$

A comparison of these figures with the last shows the precision of the observations.

Again, the following star observations were taken on March 24th with a 4-inch theodolite:

	Obs. alt.	*G. S. T.*
β Orionis	$33°\ 39'\ 36''$	$12^h\ 04^m\ 32^s.4$
α Leonis	$39\ 08\ 00$	$12\ 14\ 13\ .9$

The assumed position being:

$\phi = 43°\ 44',$ $\quad L = 5^h\ 17^m\ 12^s.$

The reduction is as follows:

h'	$=33°\ 39'\ 36''$	$=39°\ 08'\ 00''$
r	$=\ 1\ 31$	$=\ 1\ 14$
h	$=33\ 38\ 05$	$=39\ 06\ 46$
G.S.T.	$=12^h\ 04^m\ 32^s.4$	$=12^h\ 14^m\ 13^s.9$
α	$=\ 5\ 10\ 39\ .9$	$=10\ 04\ 06\ .4$
t (at *Gr.*)	$=\ 6\ 53\ 52\ .5$	$=\ 2\ 10\ 07.5$
L (assumed)	$=\ 5\ 17\ 12$	$=\ 5\ 17\ 12$

τ	$= 1\ 36\ 40.5$	$= 3\ 07\ 04.5$
	$=24°\ 10'\ 07''.5$	$=46°\ 46'\ 07''.5$
δ	$=-8°\ 17'\ 50''$	$=+12\ 21\ 32$
	log.	*log.*
$\tan\ \delta$	9.16386 *n*	9.34066
$\cos\ \tau$	9.96016	9.83565
$\tan\ \theta$	9.20370 *n*	9.50501
θ	$=180°-9°\ 04'\ 54''$	
	$=170°\ 55'\ 06''$	$=17°\ 44'\ 22''$
ϕ	$=\ 43\ 44\ 00$	$=43\ 44\ 00$
$\theta-\phi$	$=\ 127\ 11\ 06$	$=-25\ 59\ 38$
$\sin\ \delta$	9.15929*n*	9.33048
$\cos\ (\theta-\phi)$	9.78132*n*	9.95368
$\sin\ \theta$	9.19822	9.48386
	8.94061	9.28416
$\sin\ h$	9.74239	9.80030
h	$=33°\ 32'\ 38''$	$=39°\ 09'\ 11''$
$\tan\ \tau$	9.65201	0.02683
$\cos\ \theta$	9.99452*n*	9.97884
$\sin\ (\theta-\delta)$	9.90129	9.64174*n*
$\tan\ A$	9.64653*n*	0.00567
	9.74524*n*	0.36393*n*
A	$=180°-29°\ 05'\ 00''$	$=180°-66°\ 36'\ 27''$
	$=150°\ 55'\ 00''$	$=113°\ 23'\ 33''$

h (computed)	$=33°\ 32'\ 38''$	$=39°\ 09'\ 11''$
h (observed)	$=33°\ 38'\ 05$	$=39\ \ 06\ \ 46$
Diff.	$=\ -\ 5\ \ 27$	$=\ \ \ \ 2\ \ 25$

The construction of the position given by these observations is shown in Fig. 6, with the following result:

$$\phi = 43°\ 40'\ 13'', \quad L = 5^h\ 17^m\ 36^s\ ;$$

the errors in latitude and longitude being $26''$ and $1^s.3$ $(=19''.5)$, respectively, which are about as small as can be expected when using a small transit reading to $1'$.

It thus appears that, as far as the mode of reduction of the observations is concerned, the method is well adapted to the use of the explorer on land; its success, however, depends more upon the facilities at his disposal for the transportation of chronometers without disturbing their rates. Although chronometric expeditions on land have been carried out successfully in the past, it has been necessary to that end to take unusual precautions to protect the chronometers from jars and sudden changes of temperature.

UNIVERSITY OF TORONTO
APRIL, 1919

SUNSET IN THE "GOLDEN GATE"

An Essay in Elementary Astronomy

By Clarence E. Woodman

A FEW months ago (last January, to be exact) an enthusiastic amateur photographer friend of mine showed me a very beautiful, cloud-resplendent photograph, purporting to be a view of a sunset in the middle of the Golden Gate of the Bay of San Francisco, taken three days before, from the "Loggia" (or observing floor) of the Sather Tower (popularly called the "Campanile") on the Campus of the University of California.

The picture was a veritable work of art, pictorially; but it looked suspicious to me for two reasons: First, because I knew that the sun could not possibly set in the "axis" of the Golden Gate at that time of year; and secondly, because the semi-circle of the sun's disc, as shown in the photograph, was much too large. And this, by the way, is an error into which nearly every artist falls. I have never seen a drawing or a painting, depicting either sun or moon, which did not represent them as altogether too big. As an illuminating example: in this particular photograph the diameter of the sun filled just one-half of the width of the Golden Gate. Now the length of the line between Fort Point and Lime Point (the narrowest part of the Golden Gate) is very nearly one mile; and it subtends (from the Campanile) an angle of five degrees. So my friend had made his sun just about *ten times* as large as it ought to be! He confessed afterwards that his fine picture was a "fake"; that he had pasted a semicircle of opaque paper on the horizon of the negative, and printed in a "cloud effect" to simulate a sunset.

The question then arose: "When does the sun (as seen from the Sather Tower) *really* set in the middle of the Golden Gate?" The following is offered as an answer—for the special benefit of the younger readers of the Journal.

The azimuth of the axis of the Golden Gate was calculated by three separate and independent methods; and the mean value found

to be 253°; (or, to put it exactly, in the language of surveyors, N. 107° 01′ 34″ W.) The height of the Tower, and its geographical position, are of course, accurately known.

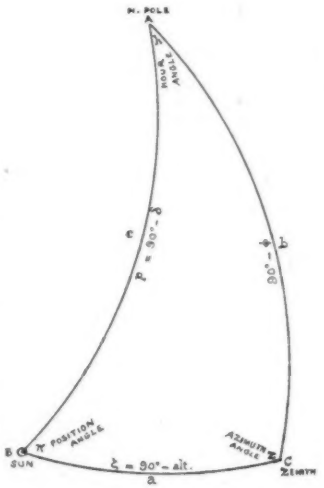
The arguments, then, are:

Azimuth (Z) of Golden Gate	= N. 107° 01′ 34″ W.
Height of eye above sea	= 521 feet.
Latitude of Tower (ϕ)	= 37° 52′ 16″ N.
Longitude of Tower (λ)	= 122° 15′ 33″ W.

For photographic purposes we take as the time of sunset the instant when the sun's *centre* is on the visible horizon. The apparent altitude is then *zero*. But this apparent altitude must be corrected for:

*Parallax for zero alt.	= +00′ 09″
Refraction " "	= −36′ 29″
Dip " 521 ft.	= −22′ 22″
Total correction	= −58′ 42″

This 58′ 42″, therefore, is the true distance of the sun's *centre* below the *true* horizon; making its zenith-distance (ζ) = 90° 58′ 42″.



Now, in the well-known "Astronomical Triangle," as here shown, we have given: the co-latitude ($90° - \phi$), the zenith-distance (ζ), and the azimuth (Z), — (two sides and the included angle), — to obtain the third side—the sun's *polar* distance (p),—and from that the sun's *declination* (δ).

The solution can be reached by the fundamental formula of Spherical Trigonometry:—

*Parallax (in seconds of arc) is very nearly 8.85 × cos altitude.

A close approximation for Refraction (for altitudes not less than 10°) is: R (in seconds of arc) = (983 b × cos alt.) ÷ (460 + t), where b is the height of the barometer in inches, and t is the reading of the Fahrenheit thermometer in degrees.

The Dip of the horizon (in minutes of arc) is practically equal to the square root of the height of the eye in feet.

$$\cos c = \cos a \cos b + \sin a \sin b \cos C.$$

(or, as it would be in the Astronomical Triangle):

$$\cos p = \cos \zeta \sin \phi + \sin \zeta \cos \phi \cos Z$$

Working this out, we have:

$\cos \zeta$ $(-.01707) \times \sin \phi$ $(.61389) = -.01048$

$\sin \zeta$ $(.99985) \times \cos \phi$ $(.78939) \times \cos Z$ $(-.29281) = -.23110$

Adding these two products, we get $-.24158$; which is the natural cosine of p. p. therefore, $= 103° 58' 49''$.

The above work involves very tedious multiplications. It may be somewhat abbreviated by the use of logarithms; thus:

log cos ζ	$= 8.23234n$	log sin ζ	$= 9.99994$
log sin ϕ	$= 9.78809$	log cos ϕ	$= 9.89729$
	$8.02043n$	log cos Z	$= 9.46658n$
	$= -.01048$		$9.36381n$
			$= -.23110$

These two numbers $(-.01048$ and $-.23110)$ and their sum $(-.24158)$ are, of course, the same as those arrived at in the former process. But even this demands unnecessary work. It is preferable to use a formula dealing with logarithmic functions only. We may do this by introducing an "auxiliary" angle (ψ), familiar to all trigonometers, such that:

$$\tan \psi = \cot \phi \cos Z$$

Then:

$$\cos p = \frac{\sin \phi \cos (\psi - \zeta)}{\cos \psi}$$

Working this out:

log cot ϕ	$= 0.10921$	log sin ϕ	$= 9.78809$
" cos Z	$= 9.46658n$		
log tan ψ	$= 9.57579n$		
ψ	$= 159° 22' 04''$	" sec ψ	$= 0.02879n$
$-\zeta$	$90° 58' 42''$		
$\psi - \zeta$	$= 68° 23' 22''$	" cos	$= 9.56620$
		" p	$= 9.38308n$
		p	$= 103° 58' 49''$

The same conclusion as was reached in the two preceding processes.

There is still another method of making this calculation; that of Napier's "Analogies;" but it is quite a lengthy one, as it requires the finding of the angles n and h before the determination of the side p. It gives the identical result, of course; and has the slight advantage of dispensing with negative logarithms.

This polar-distance (p), being more than 90°, means that the sun is *south* of the Equator, *i.e.*, has a *minus* declination (δ) of 13° 58′ 49″. The "Nautical Almanac" assigns this declination to *February 12th* and to *October 31st*, 1919, (and to practically the same dates in 1920).

To ascertain the *time* of sunset on these dates, we have the regular "sine formula" of Spherical Trigonometry:

$$\sin A = \frac{\sin a \sin C}{\sin c}$$

or, in the Astronomical Triangle:

$$\sin h = \frac{\sin \zeta \sin Z}{\sin p}$$

where h is the *hour-angle* of the sun; *i.e.*, the angle at the Pole between the meridian of the observer and the sun's meridian at the time. (The other symbols have been previously explained.)

Working this out:

log	cos	$p = 0.01306$
"	sin	$\zeta = 9.99994$
"	sin	$z = 9.98053$
"	sin	$h = 9.99353$
		$h = 80° 08′ 10″$

Reducing this to time, $h = 5$ hours 20 minutes 33 seconds.

This is, of course, *Sun* (or *Apparent*) time P.M. To reduce it to *clock* (or *Standard*) time, we must apply (1) the Equation of Time for the given date, and (2) the constant correction for longitude. The time-equation for February 12th is $+14^m\ 24^s$; for October 31st it is $-16^m\ 16^s$. The longitude (λ) of the Sather Tower is 122° 15′ 33′ W; making its local time $9^m\ 2^s$ *slow* of the local time of the Pacific "Standard" meridian,—the 120th.

Hence we have:

	For Feb.	For Oct.
Local Apparent time	$=5^h\ 20^m\ 33^s$	$5^h\ 20^m\ 33^s$
Equation of time	$=+14\ \ 24$	$-\ 16\ \ 16$
Local Mean time	$=5\ \ 34\ \ 57$	$5\ \ 04\ \ 17$
Correction for λ	$=+\ 09\ \ 02$	$+\ 09\ \ 02$
Pacific Standard time	$=5\ \ 43\ \ 59$	$5\ \ 13\ \ 19$

Therefore the sun, as seen from the Campanile of the University of California, sets in the middle of the Golden Gate at 5:44 p.m. on February 12th, and at 5:13 p.m. on October 31st, Pacific Standard Time.

NOTE—A reference to Burdwood's "Azimuth Tables" (or to those published by the U.S. Hydrographic Offices) will show, by simple inspection, the results of the above calculations: *i.e.*, the Date, the Sun's Azimuth, and the Time of Sunset.

SUNSET IN THE GOLDEN GATE.

NEWMAN HALL, UNIVERSITY CATHOLIC CHAPEL
BERKELEY, CALIFORNIA
APRIL 4TH, 1919

OBSERVATORIES IN CANADA

By Otto Klotz

OVER a year ago I prepared and published a brief paper with the above title, and believed at the time, due to my researches in the Public Archives here, that Toronto and Quebec were the only places that had observatories of half a century ago or more. By mere chance I have learned that in early days an observatory was built at Fredericton, and also one at Kingston—the one at Montreal had not been considered, for it was a purely meteorological one originally. For these three the following data after much search and correspondence have been collected, although they are not as complete as was desired.

Fredericton.—In September, 1840, Dr. William Brydone-Jack came to King's College, Fredericton, as professor of Mathematics and Natural Philosophy. Through his efforts an observatory, a modest building, was built in 1851.* "Its fine equatorial telescope, by the famous Merz and Son, was for some time the best in British America, and the other accessories were then regarded as quite up to date. The many hundreds of careful observations that the Doctor took showed that astronomical work was to him a labour of love. Soon after the observatory was built he made practical use of the lately established line of electric telegraph, and by exchange of signals with Professor Bond of Harvard University he established the true longitude of Fredericton. He afterwards ascertained the exact longitude of Saint John and of Quebec."

It is strange, most strange, that neither at Fredericton nor at Harvard are any records to be found showing that observations had been made, as well as connection by the electric telegraph, for determining the difference of longitude between the two places, although such a determination was made in 1851 between Cambridge (Harvard) and Halifax. The Quebec observatory files show letters from Prof. Jack, King's College, Fredericton, dated July 27, October 10 and Nov. 24, 1855, replying to inquiries by Lieutenant

*W. O. Raymond, Trans. Royal Society Canada, Sec. II. p. 107, 1918

E. D. Ashe, Director of the Quebec observatory, respecting the operations for determining the longitude of Fredericton by telegraphic connection with Harvard College Observatory, and giving the mode of observing, transmitting and receiving signals, instrument used, etc., but no mention is made of the results of these determinations.

Jack sends Ashe the longitude of Fredericton as: $4^h\ 26^m\ 33^s.43$. and their mean difference, Nov. 14, 15, 16, 1855, Quebec-Fredericton $0^h\ 18^m\ 15^s.14$.

Hence longitude of Quebec (Mann's Bastion, Citadel) $4^h\ 44^m\ 48^s.57$.

This value is $^s.45$ less than that obtained in 1857 directly between Quebec and Harvard whose difference was found to be $18^s.32$,

Harvard being taken as $4^h\ 44^m\ 30^s.70$.

In a letter, Aug. 23, 1855, by Lieut. Ashe to the officers of H. M. Ordnance, he says: " . . . . . and that Professor Jack has also determined the longitude of Fredericton by galvanic signals," but no dates are given when this was done. From what precedes, it would appear that the observations for longitude of Fredericton with Harvard were made in 1855.

It was considered interesting to make a comparison between the original longitude determination of Fredericton and that made by the Dominion Observatory in 1908 by the most modern instruments (transit micrometer) and methods. It is obvious that we must not use the above value of $4^h\ 26^m\ 33^s.43$, for that involves the longitude of Harvard (before cable determination), but, instead the difference Fredericton-Harvard, and add (subtract) this to the modern value of Harvard.

In a letter, October 19, 1857, by Professor W. C. Bond to Lieut. Ashe the longitude of Cambridge (Harvard) is given as $4^h\ 44^m\ 30^s.70$; now, assuming that this is the value used for Fredericton two years before, we have for the difference Fredericton-Harvard $0^h\ 17^m\ 57^s.27$.

The present accepted longitude of Harvard is $4^h\ 44^m\ 31^s.05$, hence the longitude of Fredericton, based on the 1855 difference, would be $4^h\ 26^m\ 33^s.78$. This is for the observatory at King's College.

Our astronomic station of 1908 was not at this observatory, but in the city, near the water front, not far from the corner of Regent and Campbell streets. The actual difference between the two points of observation as communicated to me by the City Clerk of Fredericton is: our station north of the observatory 3,810 feet, and west 2,150 feet, the latter equivalent to 30.45 seconds of arc, or 2.03 seconds of time. Applying this difference to the 1855 value we obtain the reduced longitude of Fredericton as $4^h\ 26^m\ 35^s.81$. This value should be in agreement or very close agreement with our 1908 value of $4^h\ 26^m\ 33^s.56$. However, a difference is found of $2^s.25$, *i.e.*, $1908-1855=-0^h\ 00^m\ 02^s.25$.

The Observatory at Kingston

It would appear that the impulse to erect an observatory in the public park at Kingston, was due to the interest aroused in astronomy by the annular eclipse of the sun on May 26, 1854, which was observed at Kingston by Lieut. Col. Baron de Rottenberg with a Dolland $2\frac{1}{4}$-in. objective, $3\frac{1}{4}$ ft. focal length; and by Fred J. Rowan with a Troughton & Simms small telescope attached to a transit theodolite. The observations were made contiguous to Murney's tower. The mean time was obtained from several double altitudes of the sun, and watches "of a description to be depended upon, with a probable error of 3 or 4 seconds."

(The above data are found in "The Canadian Journal", Vol. III, p. 177, in the March number for 1855).

Before continuing the story of the observatory, to preserve chronological order, we give the essentials of a communication of Dr. James Williamson of Kingston to the Editor of the "Canadian Journal" and which appeared in the November number, 1854. The article was on the longitude of Kingston. "Eclipses of the sun, it is well known, afford one of the most accurate means of determining the longitude, independently of such means as telegraphic communication with an observatory, the longitude of which has been already ascertained. The longitude of Kingston, as deduced from two eclipses of the sun, and one transit of Mercury, the time being taken from a carefully regulated clock, the pendulum having a wooden rod, is as follows:

By eclipse of sun, April 25, 1845	76° 32′ 45″
By eclipse of sun, May 26, 1854	76° 32′ 59″
By transit of Mercury, May 8, 1845	76° 31′ 45″

Another eclipse, May 6, 1845, the time being taken from a carefully regulated watch, gave 76° 31′. The mean of these observations, 76° 32′ 07″.25 W., may therefore be considered as the longitude of Kingston, very nearly.

A lunar distance, worked out from observations with two instruments only, and which may be rejected except as an approximation, gave 76° 30′. The mean longitude, deduced from twelve observations of immersions and emersions of Jupiter's satellites, a compartively imperfect mode of its determination, gives 76° 31′ 17″.....

The limit of error in the above mean of 76° 32′ 07″.25, is, in all probability, not more than a third to a half of a statute mile. I do not know how far the longitude and latitude of Toronto may be considered as ascertained."

In April, 1855, a special committee was appointed "for the special object of carrying out effectively the contemplated design of erecting an observatory, and obtaining a good telescope (and perhaps other instruments) in connection with the park".

Especially through the efforts and contributions of Baron de Rottenberg, Professor Williamson, Judge Burrowes and Dr. Yates an equatorial of $6\frac{1}{4}$-ins. was bought for $800 from Mr. Clark of Cambridge, Mass. The equatorial was received in the autumn of 1855, and was set up and adjusted on its pedestal under the dome of a small tower erected in the park in the spring of 1856.

In the following year, February, 1857, Lieut. E. D. Ashe observed at Kingston, near the new Court House, for the difference of longitude by the electric telegraph between Kingston and Quebec. The difference was found to be $0^h\ 21^m\ 05^s.50$, the longitude of Quebec, which had been connected with Harvard, $4^h\ 44^m\ 49^s.02$, thus giving the longitude of Kingston as $5^h\ 05^m\ 54^s.52$. In 1905 the longitude of Kingston was determined by the Dominion Observatory and found to be $5^h\ 05^m\ 52^s.864$. The place of observation for the latter is not the same as for the former, being on the Royal Military College grounds on Point Frederick, about 200 ft. from

Cataraqui Bay. Scaling from the city map the former is west of the latter 5,300 feet, or 72.8 seconds of arc, or 4.85 seconds of time. Applying this to the 1857 value, remembering that it rested on Quebec, and Quebec in turn on Harvard whose longitude was then taken at $4^h\ 44^m\ 30^s.70$, while the improved value is $^s.35$ greater, that is, $4^h\ 44^m\ 31^s.05$, it follows that the Kingston 1857 value based on the latter Harvard longitude, together with the above reduction of $4^s.85$ gives us Ashe's longitude for our 1905 station as $5^h\ 05^m\ 50^s.02$ of $2^s.84$ less than the definitive 1905 value of $5^h\ 05^m\ 52^s.86$.

In 1858 a series of observations was made on Donati's comet and published by Dr. Williamson. An application was made to Parliament for a grant in aid of the objects of the observatory. An annual grant of $500 was obtained in 1860, and the succeeding years. By its assistance the late observatory building in the city park was erected at an expense of about $1,400. The purchase of a transit circle and standard sidereal and mean time clocks, such as are necessary for a fully equipped observatory (costing at least fully $5,000) being wholly beyond the means of the friends of the institution, a small transit by Simms was purchased in the mean time (1863) for $180, and the loan of a larger instrument called the Beaufoy transit was obtained (March, 1864) by application to the Royal Astronomical Society, London, England.

The situation of the observatory in the city park was for various reasons unsuitable for carrying on useful work, and in consequence the observatory and instruments were moved to a small but neat observatory structure in the rear of the College, Queen's, in 1881.

The observatory suffered in 1909 a third location—its present location—being near the southwest corner of University Avenue and Stuart Street.

Montreal.—The observatory here, on the campus of McGill University, is chiefly concerned with meteorological work and is one of the chief reporting stations of the Meteorological Service of Canada. The original building, erected in 1862 and occupied in 1863 by Dr. Chas. Smallwood, consisted of a basement, one story and the beginnings of a small tower and was erected at a cost of $3,000. Smallwood's meteorological observations had hitherto been carried on at St. Martin, Isle Jesus, nine miles west of Montreal, and dated back as far as 1849. It was only after the

acquisition in 1879 by donation from Charles Blackman of an equatorial telescope of $6\frac{1}{4}$-ins. aperture and 7 feet focal length that astronomical work was entered upon, more especially by the installation at the same time of a Howard mean time clock, and a $3\frac{1}{4}$-in. transit, 42 in. focus, by Jones & Sons, London; also a sidereal clock was mounted. Henceforth time was furnished to the city and to the Harbour Commissioners, as well as to the various railroads centering in the city.

The first determination of the longitude of Montreal by the use of the electric telegraph was on the night of March 12, 1857, when Lieut. E. D. Ashe made a connection with the Quebec Observatory in the citadel. The point of observation in Montreal was the gardener's tool house in Viger Square. The difference of longitude was found to be $9^m\ 22^s.70$, which gave for the longitude of Montreal, Viger Square, $4^h\ 54^m\ 11^s.72$, based on the longitude of Quebec as $4^h\ 44^m\ 49^s.02$, and that in turn on Harvard as $4^h\ 44^m\ 30^s.70$. In 1883 a longitude campaign between Montreal, McGill Observatory, and Harvard was successfully carried out by Professors W. A. Rogers and C. H. McLeod, giving the longitude of the former as $4^h\ 54^m\ 18^s.543 \pm {}^s.045$ dependent upon Harvard Observatory (dome) of $4^h\ 44^m\ 30^s.993 \pm {}^s.041$; in 1892 a trans-Atlantic longitude campaign between Greenwich and Montreal with the intervening cable stations Waterville and Canso was undertaken and completed by Professor H. H. Turner and C. H. McLeod, Otto Klotz and H. P. Hollis. The resulting longitude of Montreal, McGill Observatory, was $4^h\ 54^m\ 18^s.62 \pm .024$. This latter value was communicated to the writer by the Astronomer Royal in a letter of 17 April, 1905.

In the U.S. Coast and Geodetic Survey Report for 1897 an adjustment is made of the longitude net of the United States by C. A. Schott, into which enters the longitude of Montreal, which is adjusted to $4^h\ 54^m\ 18^s.634$, a value slightly larger (by ${}^s.014$) than the value furnished by the Astronomer Royal.

It may be observed here that the latter adjusted value for Montreal (McGill) was used for the definitive longitude of Ottawa (the old Cliff-street Observatory) $5^h\ 02^m\ 50^s.022$, and on the erection of the Dominion Observatory (occupied in 1905) the value carried to the latter by observations between the two Ottawa obser-

vatories, when the value for the Dominion Observatory was found as $5^h\ 02^m\ 51^s.983$.

It will be interesting now to make a comparison between the 1857 value and that of 1897, forty years later. Lieut. Ashe connected Montreal with Quebec telegraphically on March 12, 1857, obtaining a difference, signals both ways, of

	h	m	s
Difference Quebec Observatory-structure Viger Square	0	09	22.70
Longitude of Quebec from Harvard Observatory connection	4	44	49.02
Hence longitude Montreal (Viger Square)	4	54	11.72
The Harvard longitude in 1857 was taken as	4	44	30.70
The Harvard longitude in 1897 was taken as	4	44	31.05
Hence Viger Square would become	4	54	12.07
Point of observation in Viger Square to McGill Observatory, difference in longitude 6145 ft.			5.75
Hence McGill Observatory deduced from Ashe's 1857 obser's.	4	54	17.82
McGill-Harvard campaign of 1883 gave	4	54	18.54
Difference 1883-1857 determinations	0	00	00.72
Difference 1892-1857 determinations	0	00	00.80
Difference 1897-1857 values (1897 adjusted value)	0	00	00.81

These differences of about three-quarters of a second are quite satisfactory remembering that they involve two telegraphic links, Montreal-Quebec and Quebec-Harvard, when longitude by telegraph was in its infancy, besides the link from Viger Square to McGill Observatory, although the length of this last link is believed to be confined to the accuracy of the scaling on the Montreal city map. The linear measure was furnished by the survey department of the city engineer's office who was fortunate in locating within a few feet the place of observation in Viger Square in 1857.

In 1907 the observatory at McGill was supplied (from government funds) with a Riefler astronomical clock with invar pendulum and air-tight case; this, with a modern Troughton & Simms astronomical transit, fitted with micrometer eyepiece, electrically recording on a chronograph, furnishes ample means for the accurate determination of time, which is at present the only astronomical function carried out by McGill Observatory.

It may be interesting to add the longitude determinations made by Lieut. Ashe in 1857, by means of the electric telegraph which at the time was something new in its application to astronomy. The

following extracts are taken from the Report of Progress for the year 1857, Geological Survey of Canada of which at the time Sir William E. Logan was director, while Sir Edmund Walker Head was Governor-General of British North America. The longitude differences by telegraphic circuit were all with Quebec, which in turn had been similarly connected with Cambridge Observatory (Harvard).

	h	m	s
Cambridge Observatory longitude as communicated by Professor W. C. Bond	4	44	30.70
Difference of longitude, Quebec, Mann's Bastion, Citadel, and Cambridge Observatory	0	00	18.32
Mean of signals, both ways, September 21	0	00	18.26
Mean of signals, both ways, October 9	0	00	18.38
Hence longitude Quebec Observatory	4	44	49.02
Difference longitude, Toronto, Magnetic Ob. and Quebec, mean of signals, 44.51s. and 44.31s., both ways, January 17	0	32	44.41
Hence longitude Toronto Magnetic Observatory	5	17	33.43
Difference of longitude, Kingston, near Court House, and Quebec, mean of signals (05.60s. and 05.39s.) both ways, Feb. 20	0	21	05.50
Hence longitude, Kingston	5	05	54.52
Difference of longitude, Montreal, Viger Square, and Quebec, mean of signals (23.01s. and 22.38s.) both ways, March 12.	0	09	22.70
Hence longitude, Montreal, Viger Square	4	54	11.72
Difference of longitude, Chicago (playground of the school situated to the northward of the Roman Catholic Church, Huron Street) and Quebec, mean of signals (41.44s. and 41.60s.) both ways, May 15	1	51	41.52
Hence longitude, Chicago	5	50	30.54

In the text Ashe writes, p. 235: "Chicago being placed on some charts, in a longitude differing by upwards of forty miles from that on another, it was of the greatest consequence before making a map of Canada, that the right position of Chicago should be ascertained." From this it would appear that Chicago first learned where it actually was from Canadian observations! Continuing:

"The electric current was transmitted via Toledo, Cleveland, Buffalo, Toronto and Montreal, a distance of 1,210 miles, by one entire connection between the two extreme stations, and without any intermediate repetition, and yet all the signals were heard distinctly at either end of the line; the signals occupied only .08 of a second in passing along that distance."

	h	m	s
Difference of longitude, Windsor (20 yards westward of Court House) and Quebec, mean of signals (19.04s. and 18.97s.) both ways, August 18	0	47	19.00
Hence longitude of Windsor	5	32	08.02
Difference of longitude, Collingwood (railway terminus) and Quebec, mean of signals (01.43s. and 01.59s.) both ways, Sept. 1	0	36	01.51
Hence longitude, Collingwood	5	20	50.53
Difference of longitude, Ottawa (120 yards east of flagstaff on Barrack Hill) and Quebec, mean of signals (59.24s. and 59.30s.) both ways, November 14	0	17	59.27
Hence longitude of Ottawa	5	02	48.29

Barrack Hill referred to, is what we now call Parliament Hill. The position of the flagstaff we know fairly accurately, for the flagstaff of 1857 was replaced by another and it in turn was removed from the knoll which it occupied for the present statue of Queen Victoria. From Brophy's plan of the city of Ottawa on a scale of 800 ft. to the inch, showing the position of the buildings, monuments, etc., on Parliament Hill it is found that the position of the old observatory on Cliff Street is 1,340 ft. west of the old flag staff, hence 1,340 ft. plus 120 yards or 1,700 ft. west of the astronomic station of 1857, equivalent to $1^s.59$.

	h	m	s
Hence position Cliff Street Observatory deduced from 1857 observation is	5	02	49.88
Cliff Street Observatory 1896 determination	5	02	50.02
Difference 1896-1857	+0	00	00.14

In continuation of my former paper, the following two letters have been furnished me by Dr. A. Shortt, Chairman of the Board of Historical Publications, Public Archives, Ottawa.

Q. 394-1.
p. 140.

TORONTO, UPPER CANADA,
13th January 1836.

My Lord,

The recall of His Excellency Sir John Colborne having arrived here at the same time with the accompanying registered N°. 361 letter to your Lordship rendered it impracticable for me to obtain His Excellency's promised support to the views of my brother.

Being conscious that my brother is perfectly capable of undertaking the office he is desirous to obtain, and naturally anxious that he should return to the service of his native country, has emboldened me to forward his application for your Lordship's consideration.

I have the honour to be
My Lord
Your Lordship's
Most obedient Servant
R. H. Bonnycastle
Capt^n. Royal Engineers.

The Rt. Honb^le. Lord Glenelg &c &c &c

Endorsed—1836 Jan^y. 13 Capt Bonnycastle, R.E. in behalf of his brother whose Memorial he encloses—for the place of Astronomer in U. Canada.

Q. 394-1.
p. 141.

UNIVERSITY OF VIRGINIA
Dec^r. 22^d.. 1835.

My Lord,

His Excellency Sir John Colborne having been good enough to inform me that it is the intention of the British Government to appoint an Astronomer in Upper Canada, and having with great kindness, expressed himself in favour of an application on my part, I have been induced to present myself as a candidate for the situation.

The emolument of my present Professorship, £1100 a year, seems to be considerably greater than the salary proposed, but as the office is under the Government of my own country, and is expressly created for the advancement of objects to which I have dedicated my whole attention, I should not hesitate about the sacrifice of a few hundred a year.

The recent suggestion of the British Association for the Promotion of Science, —to erect in various parts of the world, observatories for making magnetic and meteorological observations may probably have been the occasion of the appointment contemplated. Proceeding on this belief, I (p. 142) have thought myself not altogether unqualified for the station. Educated by the Admiralty for mathematical pursuits nearly connected with that branch of the service, and long devoted to the study of magnetism, I succeeded about a dozen years since in first developing the theory since further completed by Poisson & others. The notice which my publication of this theory attracted and the instant adoption of it by so competent a judge as Professor Barlow of Woolwich, leads me to suppose that I should be regarded as qualified to pursue this important branch of an observer's duties. With respect to the purely astronomical department I must appeal to the accompanying certificates. Constantly employed in this University in teaching the highest branches of the theory of Astronomy, and assisted in the practice by the command of a small observatory furnished under my directions with a few excellent Instruments I have possessed the opportunities necessary for acquiring a proficiency in this subject.

For testimonials of a more general character—I appeal to Professor Barlow of Woolwich—to the Work in Geometry which I have published in this Country, and to the accompanying papers; the latter of which will go to prove that in the offices (p. 143) of Professor of Natural Philosophy, Professor of Mathematics and Chairman, I have received whilst at this University, the full approbation of those whose duty it was to scrutinize my conduct. The fact that in an Institution

where the reputation of the Professor is allowed to govern the size of his school, my classes have always been among the largest, and of late years have been very far the largest, will I trust also support my pretensions.

Should these be thought sufficient to justify the acceptance of my tender of service, your Lordship by bringing me again under the dominion of my native country, of which I have, & shall always continue a subject, will gratify an ardent desire, but if some other person should on the contrary be found better entitled to the situation, I must request you to receive my assurances of the respectful feelings with which I shall acquiesce in your Lordship's decision.

I remain

Your Lordship's

Very obed^{t} humble Sert.

C. Bonnycastle.

The R^{t}. Hon^{le}

Lord Glenelg

&c &c &c

Endorsed—1835. December 22.

M. Bonnycastle Professor of Astronomy in Virginia, wishes to be Astronomer in U. Canada.

No appointment was made and it was just half a century later—1885—when the word Astronomer was for the first time officially used by the Dominion Government on the initiation of astronomic work along the Railway Belt in British Columbia.

In a letter of October 21, 1836, by the Astronomer Royal, G. B. Airy to Mr. C. Wood, Secretary to the Admiralty, the contents of six boxes containing the instruments received (inspected and repaired) from St. Helena, are given. These were the instruments that the Admiralty was prepared to send to Upper Canada (Toronto) if Upper Canada would meet the necessary expenses of installation, but the provincial finances were at the time unsatisfactory so that nothing was done.

An abstract of the principal parts of the above contents may be interesting: A mural circle of 4 feet diameter; 6 micrometer microscopes, two of the microscopes have diagonal eye-pieces, and other accessories; observing chair; clock by Barrand, dead beat escapement; telescope 4½ inches aperture, and length 6 feet, one erecting and three astronomical eye-pieces, one dark glass, and a single wire position micrometer with two eye-pieces; and stand for telescope "admitting of nice motion by two screws, but perfectly steady. The telescope cannot however be raised to the zenith".

OTTAWA, DOMINION OBSERVATORY
MAY 27, 1919

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada.

June, 1919.

Temperature.—The mean temperature was slightly below normal in British Columbia and in Nova Scotia, while from the Rocky Mountains to Northern New Brunswick it was much above. The greatest positive departures, amounting to about 9°, occurred in Western and Northern Ontario, gradually diminishing toward both the east and west.

Precipitation.—Precipitation was above the average in some parts of Northern British Columbia, over the greater part of Manitoba, the counties bordering on the St. Lawrence River in Ontario and the more southern counties of Quebec; while in other parts of the Dominion it was much below. The total fall over a large portion of Alberta and in southwestern Saskatchewan was less than one inch.

July, 1919.

Temperature.—The mean temperature was below normal in British Columbia, in the districts contiguous to the Gulf of St. Lawrence in Quebec, and in the Maritime Provinces, while throughout the Prairie Provinces, Ontario, and the greater portion of Quebec the normal was exceeded. The negative departures were small, varying between 1° and 3°, and the positive departures, which were greatest in the southern districts of Alberta and Saskatchewan and in Western and Northern Ontario, did not exceed 5°.

Precipitation—The heaviest precipitation occurred in northwestern Quebec and in the basins of the St. Maurice and the Chaudière in the same province, while it was somewhat less heavy on the shores of the Bay of Fundy and in the central tier of counties of the Peninsula of Ontario. In the districts mentioned the monthly totals ranged from 3 to 5 inches, except in the Lake St. John region of Quebec, where they ranged from 4 to 9 inches.

In Manitoba and a part of eastern Saskatchewan the precipitation was, in general, normal or somewhat in excess, as was the case also in the basin of the Upper Fraser River in British Columbia.

Elsewhere in Canada the precipitation was generally in defect of normal, especially in Alberta and Saskatchewan, where (with the exception already noted) from 1 to 2 inches less than normal were recorded. The total fall for the month was less than an inch in some districts of southwestern Saskatchewan.

In southern British Columbia, the southwestern extremity of the Peninsula of Ontario and on the west shore of Lake Superior, the precipitation was also very scanty.

EARTHQUAKE RECORDS BY THE MILNE SEISMOGRAPH TORONTO.
SIR FREDERIC STUPART, DIRECTOR.

P.T. = Preliminary Tremors. S. = Secondary Waves. L.W. = Large Waves. A.C. = Air Currents. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1919	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks.
		h m	h m	h m	h m	h m	mm.	
*2007	June 2			6 59.3	6 59.8	7 03.1	0.2	Doubtful as to being seismic.
2008	" 10			20 57.9	20 58.6	21 03.8	0.1	
2009	" 15				16?17.9		0.1	Small micros going on.
2010	" 15				18 05.6		0.1	Small micros going on.
2011	" 29			1 03.3 1 12.0			0.1	Small micros of uniform character and intervals going on 0 h. 30.5 m. to 1 h. 13.7 m.
2012	" 29			15 39.8	15 43.6	15 50.2	0.1	
2013	" 29	23?21.9	23 26.4	23 32.2	23 33.4	0 30.4	2.1	2830 Km. Possibly W. Indies.
2014	" 30			8 22.5	8 45.2	9 10.2	0.2	
2015	July 1			21 49.4		22 23.0	0.2	Times doubtful
2016	" 2			8 01.6		8 22.8	0.05	
	" 4	Micros	after 10	hrs. to early	morning	of 5th.		
2017	" 6	7?11.0	7 15.6	7 17.6	7 23.9	7 38.5	0.2	Micros before P.
2018	" 7		14?57.5	15 00.9	15 04.9	15 12.9	0.2	Gradual thickening.
2019	" 8	Micros.		22 01.0 22 10.7	22 16.1	Micros.	5.0	Earlier phases masked by micros.
	" 9	Heavy	micros	masked	disturbance	recorded	at	other stations.
2020	" 10			2 40.5			0.2	Micros going on.
2021	" 11			0 46.3	0 56.3	1 26.5	0.1	
2022	" 12			22 42.1			0.1	Small micros going on.
2023	" 14	14?13.9		14 23.0 14 31.8	14 38.5	15 03.5	0.2	
	" 17	Micros	at 11:18.					
2024	" 17	16 26.5	16 33.9	16 39.4	16 48.7		0.3	
2025	" 18			13?25.0				Phases interfered with Inspecting instrument.
2026	" 22	22?08.1	22 14.0	22 19.8	22 22.2	Micros.	0.2	
2027	24			2 47.7 2 57.1	3 02.1	3?27.3	0.2	
2028	" 25			19 13?8 19 19.6		·	0?2	Marked micros going on.
					8 10.5 to 8 12.4			
2029	" 31			8 06.6		8 18.3	0.2	Gradual thickening.
2030	" 31			22 05.9 22 12.5		Micros.	0.1	

Period of boom 18 seconds. Pillar inclination 1 mm = 0″.45.

*The following quake was left from the May report, consequently changing the numbers.

May 23			3 33.6	3 40.2	4?05.0	0.1	

VICTORIA, B.C.

F. NAPIER DENISON, SUPERINTENDENT.

No.	Date 1919	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks.
		h m s	h m s	h m s	h m s	h m s	mm.	
*								
2004	June 2	7 13 13			7 14 02		0.1	May not be a quake.
2005	" 10			21?03 00	21 09 24	12 14 29	0.1	
2006	" 11				6?55 09		0.05	May not be a quake.
2007	" 14				8 01 32		0.1	
2008	" 15			16?25 24	16 27 23	16 30 51	0.2	
2009	" 15	17?44 14			17 46 13	17 50 11	0.3	
2010	" 29	1?06 00			1 06 59	1 12 53	0.5	
2011	" 29				15 51 48	?	0.2	
2012	" 29	23?22 19	23?28 42	23 38 03	23 48 12	0 46 14	1.8	
2013	" 30				8 44 00	9 19 44	0.2	
2014	July 1	21 50 29			21 51 58	22 01 19	0.5	
2015	" 1	22 05 15		22 06 14	22 07 13	22 12 08	0.5	
2016	" 2			8 25 12		8 29 36	0.05	
2017	" 6	7?15 53	7 19 11	7 24 49	7 28 47	7 41 09	0.2	1940 Km.
2018	" 7	14?21 47		14 35 17	14 43 47	14 59 47	0.4	*
	" 8	Quake missed, light off the paper.						
2019	" 9	19 35 18	19?37 46	19 38 44	19 01 22	19 48 34	0.4	1410? Km.
2020	" 10	2 23 03		2 23 33	2 24 02	2 33 23	0.3	
2021	" 11			1 06 56	1 14 18	1 30 02	0.2	
2022	" 17		16?49 48	16 53 14	16 57 10	17 18 49	0.4	
2023	" 18	13 38 20			13 40 18	13 45 03	0.3	
2024	" 22			22?35 02	22 38 58	22 42 54	0.2	
2025	" 24	2?45 16		2 50 13	3 04 07	3 23 22	0.4	
2026	" 25			19?16 37	19 20 35	19 25 03	0.4	
2027	" 31				7 50 57	8 25 52	0.2	
2028	" 31			21 58 25	22 00 43	22 06 19	0.05	

*The following was omitted from the May report consequently numbers are changed.

May 23			3 45 54	3 51 48	3 55 00	0.05	

Period of Boom 18 seconds. Pillar inclination 1 mm =0.″54

VERTICAL SEISMOGRAPH.

" 18	13 38 16		13 39 46	13 40 36	13 49 46	7	660 km.

TEMPERATURES FOR JUNE AND JULY.

STATION	JUNE. Highest	JUNE. Lowest	JULY. Highest	JULY. Lowest	STATION	JUNE. Highest	JUNE. Lowest	JULY. Highest	JULY. Lowest
Yukon					Saskatoon	94	26	104	42
Dawson	80	28	86	38	Souris	89	33	98	42
British Columbia					Swift Current	95	21	102	43
Atlin	65	31	77	34	Winnipeg	88	34	90	45
Agassiz	86	35	92	44	*Ontario*				
Barkerville	77	30	78	33	Agincourt	92	44	94	48
Kamloops	96	39	102	48	Bancroft	95	36	93	39
New Westminster	80	41	86	49	Barrie	90	43	93	47
Prince Rupert	63	38	68	47	Beatrice	94	37	91	38
Vancouver	74	42	81	46	Bloomfield	89	45	92	48
Victoria	70	43	84	47	Brantford	94	45	98	50
Western Provinces					Chapleau	95	42	93	36
Battleford	97	30	103	42	Chatham	99	47	98	50
Calgary	95	27	97	41	Clinton	92	45	95	43
Edmonton	89	30	87	47	Collingwood	100	40	104	40
Medicine Hat	103	33	103	47	Cottam	94	45	95	54
Minnedosa	98	28	98	42	Georgetown	89	43	93	50
Moosejaw	101	25	101	40	Goderich	95	34	94	34
Oakbank	86	29	86	42	Gravenhurst	94	39	93	47
Portage la Prairie	87	37	93	49	Grimsby	94	47	96	51
Prince Albert	93	30	94	44	Haliburton	100	35	98	38
Qu'Appelle	94	33	92	39	Huntsville	94	37	93	42
Regina	100	25	97	36	Kenora	90	39	86	53

TEMPERATURE FOR JUNE AND JULY—*Continued.*

STATION	JUNE.		JULY.		STATION	JUNE.		JULY.	
	Highest	Lowest	Highest	Lowest		Highest	Lowest	Highest	Lowest
Kinmount	96	39	95	44	Toronto	94	47	98	52
Kingston	91	48	88	55	Uxbridge	92	40	96	44
Kitchener	91	43	95	47	Wallaceburg	93	40	95	49
London	96	45	98	46	Welland	94	45	94	51
Lucknow	92	40	94	41	White River	90	26	93	31
Markdale	93	40	94	44	*Quebec*				
North Gower	95	39	—	—	Brome	—	—	89	46
Oshawa	93	50	90	50	Father Point	76	34	84	40
Ottawa	96	45	97	50	Montreal	92	43	91	54
Paris	95	42	100	45	Quebec	93	39	88	48
Parry Sound	96	42	98	46	Sherbrooke	93	41	91	42
Peterborough	97	41	96	48	*Maritime Provinces*				
Port Arthur	86	40	92	42	Charlottetown	82	38	78	38
Port Burwell	87	46	—	—	Chatham	92	34	92	42
Port Dover	94	47	91	52	Fredericton	90	30	92	46
Port Stanley	90	44	86	47	Halifax	86	34	84	46
Queensborough	93	39	92	47	Moncton	87	34	—	—
Ronville	93	37	95	42	St. John	84	37	82	47
Southampton	93	42	94	46	Sussex	88	28	88	42
Stonecliffe	98	26	98	28	Sydney	84	34	80	42
Stoney Creek	91	45	97	52	Yarmouth	78	38	82	42

BOOK REVIEWS

L'Origine des Formes de la Terre et des Planètes, par E. Belot, Ancien Elève de l'École Polytechnique, Directeur des Manufactures de l'État. 209 pages. Paris: Gauthier-Villars, 1918. Price 14.40 frs.

This is a work on an interesting and important subject by an able French scientist. The present writer is not competent to write a critical analysis of it, but gives the following paragraphs from the notice supplied by the publishers:

In this book the author has attempted to write the first chapter of the Earth's history, between its gaseous condensation at a high temperature, according to the notions of Laplace, and the dawn of the precambrian epoch. The physics and mechanics of fluids (nebulous fluid, primitive atmosphere, igneous fluid of the earth kernel) have furnished him a striking link between geology and the primitive nebulous cosmogony, the dynamic forces of which he has been able to determine by the aid of the new laws of the solar system, set forth in his "Essai de la cosmogonie tourbillonnaire" (Gauthier-Villars, Paris 1911). The earth's history has thus been taken for the first time at its beginning, instead of at its end as geologists have hitherto done.

An additional and pathetic interest is found in the dedication, which reads:

To the memory of my only and well-beloved son, Paul Belot, Senior Scholar in the Polytechnic School, 2nd Lieut. in the 7th Regiment of Artillery, killed gloriously for France and the liberty of the World at the age of 24 years, at Jonchéry, near Suippes (Marne), on September 21, 1914.

ASTRONOMICAL NOTES

The Motions in Space of Some Stars of High Radial Velocity

Proceedings National Academy of Sciences, U.S.

A few of the more important conclusions may be indicated briefly.

1. The highest velocity in space found for any star is 494 km. for the ninth magnitude star A. G. Berlin 1366. Several other stars with larger parallaxes show values of nearly this amount. In all cases the components of motion in the place of the galaxy exceed greatly those at right angles to it.

2. For the stars as a whole we find the two components in the galactic plane very nearly equal and more than two and one-half times as great as the component perpendicular to it. We find a similar result from a consideration of the latitudes of the apices. Only 6 out of the 37 stars have apices with latitudes exceeding 30°. It is clear, therefore, that the influence of the galactic condensation is very marked upon the motion of these stars.

3. Nearly an entire hemisphere in longitude is devoid of apices, the values all lying between 131° and 322°.

4. The velocity of the centroid of these stars is remarkably high. Thus even if we omit total velocities greater than 300 km. we find a value for the centroid of 74 km. This motion is almost wholly in the galactic plane.

5. The effect of stream motion among these stars is very marked. The axes for which the sum of the squares of the protected velocities is a maximum and a minimum have longitudes of 141° and 61°, respectively, and latitudes of +9° and −49°. The mean square dispersion along the major axis is over twice that along the minor axis. The value for the major axis is in close agreement with that found by Strömberg from a discussion of the

radial velocities of 260 dwarf stars, and with that of Raymond from 559 stars of large proper motion. All of these investigations indicate that the galactic longitude of the principal vertex for the stars of high velocity is considerably less than that for stars in general.

6. There appears to be some tendency for the stars to move along a line of galactic longitude about 260°, allowance being made for the motion of the centroid. This direction coincides nearly with that of the greatest star density as determined by various observers.

7. The stars of highest velocity, over 300 km., also appear to move along a line parallel to that of the major axis when the motion lis referred to their common centre.

8. The average galactic latitude of the apices of the stars of high luminosity is nearly twice as great as that of the fainter stars, the values being 26° and 14°. The latitudes of the apices of only four of the fainter stars exceed 26°.

9. The average space-velocity of the stars of low luminosity is much larger than that of the brighter stars. Twenty-eight stars of average absolute magnitude 5.9 show a velocity of 216 km. Nine stars of absolute magnitude 0.4 a velocity of 130 km.

10. An extraordinarily large proportion of the stars in this list, 26 out of 37, are of types F and G. The successive types F, G, K and M show average space-velocities of 307, 156, 122 and 121 km. respectively, the weight of the determination for the last two types being rather low. Among the stars of type F those of earlier spectral type show the larger velocities. Thus the six stars with spectra between F_0 and F_5 inclusive have an average velocity of 365 km. as against 307 km. for all stars of the F type.

The most important result of this brief investigation is the evidence for the marked influence of the condensation of matter in the plane of the stellar galaxy upon the motions of these relatively faint stars. Their susceptibility to stream motion is perhaps another result of the same general influence which is, no doubt, gravitational in character. Probably the most peculiar fact in connection with these stars is the spectral type of the stars of highest velocity. That a type which we are accustomed to consider as intermediate in the scale of stellar development should contain so large a proportion of the most rapidly moving stars is

difficult of explanation unless we may assume that these stars are of exceptionally small mass. Since the relationship of velocity to absolute magnitude seems to be fairly well established this hypothesis may be worthy of consideration.

—*W. S. Adams and A. H. Joy.*

ATMOSPHERIC CONDITIONS FOR OBSERVING.

There is a general impression among astronomers that in order to secure the best seeing we should go to a dry climate. Indeed the sites of a number of observatories have been selected in the last thirty years with this idea in mind. This view is quite erroneous. In order to put the matter to a test however, we measured the dew-fall here on fifteen nights when the seeing was unusually bad, 3 and 4 on the standard scale. We also measured it on thirteen nights when the seeing was perfect as far as we could judge with our 11-inch aperture, namely 12 on the standard scale. On the nights of poor seeing the average dew-fall was 3.6 cubic centimeters per square meter. On the nights of good seeing it was 108.1 cubic centimeters, or just thirty times as much. Instead therefore of finding good seeing associated with a dry atmosphere, we find that precisely the reverse is the case.—Mandeville, Jamaica.—*W. H. Pickering, Pop. Astronomy, No. 267.*

NOVA AQUILÆ.

1. Measures of wave-lengths of the bright bands, in the spectrum of Nova Aquilæ, 1918 July 29, are compared with the wave-lengths of the dark lines in the stars γ Orionis and α Cygni.

2. Excluding the well-marked nebular bands, the more prominent bands, chiefly helium, agree in intensity rather with γ Orionis than with α Cygni.

3. The fainter bands belong to the α Cygni type of spectrum.

4. Several of the bands, particularly those of hydrogen, are triplets.

5. There is evidence to show that, besides a stationary spectrum, there is a spectrum, indicating a line-of-sight motion of recession of about 1160 km./sec., and a similar spectrum indicating a line-of-sight motion of approach of about 1340 km./sec.—*Rev. A. L. Courtie, Monthly Notices, R.A.S., Vol. LXXIX, No. 7.*

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

The Magnetic Polarity of Sunspots.

The receipt of a sheaf of *Contributions* from the Mount Wilson Observatory shows that this institution is busy reaping a fine harvest of scientific results from its numerous investigations. One of the most interesting of these publications is No. 165, on "The Magnetic Polarity of Sun-spots", by Messrs. Hale, Ellerman, Nicholson and Joy.

Whirling storms in the earth's atmosphere, such as cyclones and tornadoes, always rotate in the left-handed, or counter-clockwise, direction in the northern hemisphere and in the right-handed direction in the southern hemisphere. In 1908 Hale showed that there were vortical motions about sun-spots and also that these motions gave rise to a magnetic field. In addition, great masses of hydrogen were observed while being sucked into a vortex. It was for some time believed that the direction of rotation in the vortex had a definite relation to the hemisphere of the sun, but this is not the case.

However, a close study of the magnetic conditions of sun-spots has enabled the Mount Wilson observers to deduce certain very interesting laws. By the means which they have perfected the magnetic polarity of a spot at almost any place on the sun's disc can readily be determined, and indeed a scheme has been devised for classifying spots on the basis of their magnetic qualities.

It has been found that about 60 per cent of all spots are binary groups, the single or multiple members of which are of opposite polarity; also that unipolar spots (that is, single spots, or groups of small spots, having the same magnetic polarity) exhibit some of the characteristics of bi-polar spots. Another remarkable fact is that before the last sun-spot minimum (December 1912) the magnetic polarity of unipolar spots and of the preceding (or westerly) members of bipolar spots was positive in the southern and negative in the northern hemispheres of the sun, and since the minimum these signs have been reversed.

Remarkable Solar Glows.

(*By A. F. Hunter*).

On June 2nd and 3rd, 1919, both morning and evening, red solar glows of unusual interest and intensity made their appearance at Toronto and other contiguous parts of Ontario and New York State, an hour before sunrise and an hour after sunset. These remarkable phenomena could scarcely belong to the afterglow phenomena, as seen under ordinary circumstances, but were rather auroral in character and belonged to very great altitudes in the earth's atmosphere, as periods devoid of much colouring lasted for a considerable time between the lurid condition of the northern sky and the actual appearance of the sun at the horizon. In other words, the phenomena could only issue from cathode rays having their origin in the sun and being much bent around the earth by its magnetism. The most intense example of the series of displays was that of the night of June 2. Most people fancied that these glows came from large fires somewhere, and the popular illusion was increased by the darkness and the length of time from the sun's disappearance or to its emergence. The newspapers of the same dates contained accounts of the phenomena which helped to correct the popular illusion.

(The above was inadvertently omitted from last number).

Our New Printers.

Our readers will have noticed a change in the appearance of the Journal. This is due to a change in printers. For over fifteen years Mr. Z. M. Collins printed the *Transactions* and later the Journal in a very acceptable manner, but his recent removal from Toronto caused him to relinquish the work. A contract has now been made with the University Press, which has excellent facilities for this sort of printing. The Press was organized some years ago for the purpose of printing the examination papers, stationery and other similar supplies, and it has now grown to considerable dimensions. Besides printing the calendars, examination papers, stationery and numerous announcements of the various departments, it does the binding for the Library and issues some books. In addition it prints several journals somewhat similar to our own and renders a very useful service to various societies and organizations. It is located in the basement of the University Library.

C. A. C.